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N. D. Vinh

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Because of the longitudinal pressure gradient and the existence of a pressure difference between the tank and the test section (Figure 1), secondary forces will falsify the measurements of the floating element balance. These forces can be attributed to: (1) The distribution of the floating head and (2) the flow across the slit [4].

Here we will study the behavior of a circular floating element balance having a diameter of 127 mm [1] in a two-dimensional turbulent flow with moderate adverse pressure gradients

$$\Delta_{max} = \left(\frac{\nu}{\rho U_\tau^3}\frac{dp}{dx}\right)_{max} = 0{,}01 \qquad [2]$$

In the first place, because of the longitudinal gradient of the adverse pressure, there is a static pressure distribution inside the flow which produces a force in the direction opposite to the direction of the wall friction. This static pressure force is in general small compared with the true friction force for sufficiently small floating element thicknesses, except for the vicinity of the separation region of the boundary layer. In the case of a circular element, we can determine it by

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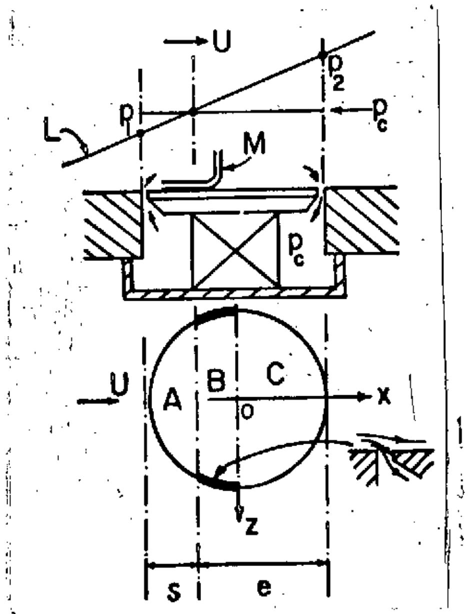


Figure 1. L: variation of static pressure in the test section; M: Preston tube; e: entering flow; s: departing flow

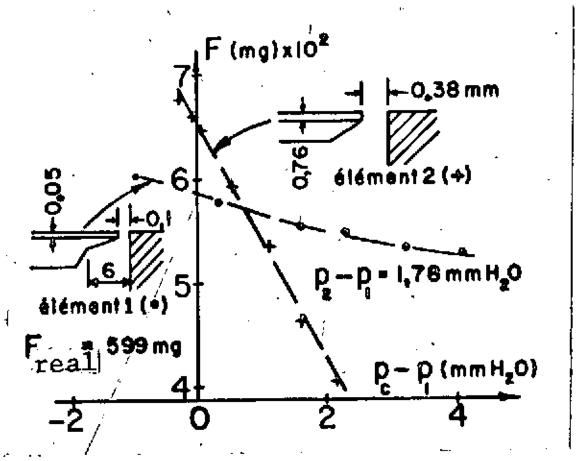


Figure 2.

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means of the following relationship [2, 3]:

$$F_{st} = \frac{1}{2}\varepsilon\frac{dp}{dx}S,$$

where ε is the thickness of the floating element, dp/dx the longitudinal pressure gradient $(p_1 - p_2)/D$ and S the area of the floating element ($\pi D^2/4$). For a given floating element geometry and a given flow configuration, this force represents a constant fraction of the friction force. In our case it is on the order of 2% maximum for the element 1 and 8% for element 2 (Figure 2). In addition, experience shows that it is independent of the tank pressure $p_c$, at least for $p_1 \leqq p_c \leqq p_2$.

Secondly, the flow across the slot partially perturbs the main boundary layer and reduces the local wall friction over part of the surface of the floating element (Region A, Figure 1). In order to restrict this "perturbing" zone of the flow, we reduced the tank pressure $p_c$ by using aspiration pipes. It should be noted that for the Element 1 (0.1 mm slot) when $p_c$ approaches $p_1$, the force recorded by the balance goes towards the one recorded by a Preston tube without the slot (Figure 2). However, this characteristic was not found in the case of Element 2 because its larger dimension (0.76 mm instead of 0.05 mm) makes the stagnation pressure effect more important for the two sides of the floating element (Region B and its diagram in Figure 1). In any case, since this stagnation pressure force acts in the direction opposite to that of the force $F_{st}$ which is not negligible for Element 2, we have shown that by the selection of the value of $p_c$, it is possible to suppress the two errors [2].

In order to evaluate the reduction in the wall friction produced by the "perturbing" flow over the floating element, we displaced a Preston tube with a diameter of 0.81 mm along the flow starting at the edge of the floating element. We also noted the indications given by this tube for a variable pressure $p_c$ range with and without the slot (very thin adhesive paper was used to produce the conditions "with and without the slot"). /1117
These results allow us to experimentally determine the percentage reduction in the wall friction for various tank pressures $p_c$ (see [2]).

Figure 3 shows that by reducing $p_c$, the influence of the flow across the slot is minimized. However, for Element 2, as mentioned above, it is necessary to retain a pressure $p_c$ slightly less than $(p_1 + p_2)/2$ in order to suppress $F_{st}$ and the stagnation pressure at the same time, and to then correct the effect of the "perturbing" flow by the determined percentage of reduction [2]. The inlet flow C (Figure 1) upstream of the floating element has no influence on the pressure recorded by the

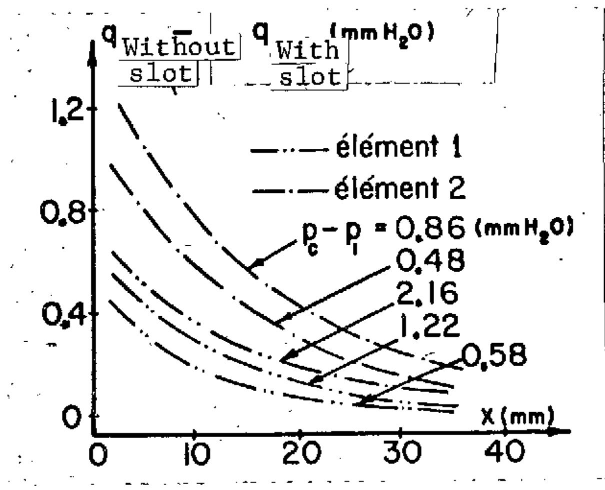


Figure 3. q: dynamic pressure recorded by the Preston tube; x: measured from the edge of the floating element (z = 0)

Preston tube located upstream, at least for $p_1 \leqq p_c \leqq p_2$.

In conclusion, for an element with a sufficiently small thickness (for example, Element 1) and for moderate adverse pressure gradients, the secondary force due to the static pressure gradient is small compared with the true wall friction force. Also, it is possible to minimize the error produced by the outgoing flow upstream of the slot by reducing the tank pressure. The friction values found in this way for Element 1 and for Element 2 (after correction) are close to those obtained using the Preston tube (calibration formulas of V. C. Patel) or by the method of Dickinson [5].

## REFERENCES


1. Dickinson, J. and V. Ozarapoglu. The Determination of Turbulent Skin Friction. Defense Research Board of Canada Progress Report, Grant No. 9550-23, October, 1969.

2. Vinh, Nguyen Duy. Measurements in a Turbulent Boundary Layer with Moderate Adverse Pressure Gradients (Professor Thesis, Laval University, Quebec, January, 1973).

3. Brown, K. C. and P. N. Joubert, J. Fluid Mech., Vol. 35, Part 4, 1969, pp. 737-757.

4. Ozarapoglu, V. and Nguyen Duy Vinh. Measurements in a nearly Separating Turbulent Boundary Layer (Third Canadian Applied Mechanics Congress, Calgary University, May, 1971)

5. Dickinson, J. Journal of Mechanics, Vol. 3, No. 1, March, 1964.



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16. Abstract

The use of a floating element balance for determining the wall friction in a turbulent boundary layer with moderate adverse pressure gradients is not limited by the existence of secondary forces. In effect, no corrections are necessary if a floating element is selected with a sufficiently small thickness in order to suppress the force due to the distribution of the static pressure in the interior of the slot. In addition, by reducing the tank pressure, the air produced by the flow through the slot is minimized.

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